

# **Economic Evaluation of Switchgrass for Biofuel in Massachusetts**

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Massachusetts Division of Energy Resources

*Creating A Greener Energy Future For the Commonwealth*

## **Introduction:**

Switchgrass (*Panicum virgatum* L.) has been identified as an energy crop with potential for biofuel in Massachusetts. Currently the University of Massachusetts is evaluating 12 switchgrass varieties for adaptability and production in Massachusetts. The focus of this project will build on the existing project by providing an initial evaluation of the economic feasibility of growing switchgrass as an alternative energy source in Massachusetts.

Information on varieties suited for planting in Massachusetts is lacking. Farmers in Massachusetts do not have good access to any local information on growing switchgrass or suitability of available varieties for Massachusetts. Further, the quality of seed is often of poor quality (low germination, with the possibility contaminated with weed seeds) and varieties available may not be suited in all regions. Also, there is a lack of information on the management of switchgrass for biofuel production.

## **Objectives:**

Our major objective is to evaluate production and harvest costs for switchgrass to determine if it is feasible as an alternative crop for Massachusetts farmers, and to determine its long-term potential as a locally grown crop for biofuel generation.

Specific objectives are as follows:

1. Develop partial budgets for switchgrass in Massachusetts.
2. Evaluate costs and management options for small to large switchgrass production in relation to other agronomic crops that could be grown by farmers.
3. To identify production potential in each county of Massachusetts under alternative yield scenarios.

## **Methods:**

### **1. Evaluation of Switchgrass Production Systems.**

A review is made of the production systems currently used for switchgrass in the United States and Canada. This considered seed sources, soil preparation, seeding methods, weed control options, dormancy and early establishment practices, fertilization, pests and diseases, and harvest and storage. This comprehensive analysis enabled the development of partial budgets and cost structure for large scale planting of switchgrass in Massachusetts.

The testing site at the UMass Crops Research and Education Center Farm established with funding from the Massachusetts Dept. of Agricultural Resources provided local data on management and yield potential in Massachusetts. However, this will not provide all

the information needed for an economic evaluation. Therefore we used two larger-scale production areas in Eastern U.S. to determine production practices, harvest and post-harvest storage and handling, and associated costs. Also, two trips were coordinated with other researchers in Pennsylvania and Nebraska. These site visits to large-scale production and experimental plantings provided a greater understanding of crop adaptability and seasonal production methods and constraints. During the visit to Nebraska Ken Vogel (Vogel, 2007) shared his PowerPoint presentation on switchgrass economics.

## **2. Partial Budget Development.**

Partial budgeting is a common economic method to make adjustments to the farm to accommodate new crops. This is convenient when the farms need not go through a complete and full reorganization. This approach is appropriate to studying economics of Switchgrass production in Massachusetts. The partial budgeting method is used to determine establishment and production costs incurred or anticipated with farm-scale production of switchgrass.

This includes all aspect of field production from seed procurement and land preparation and storage costs, and will project potential yields and costs per ton for each land type and yield class. The partial budgets are developed using estimates of switchgrass production in farms in Iowa (Brummer et al., 2002), and New York. Input use and price information from Massachusetts farms is used in calculating the budgets relevant to Massachusetts. The budgets are reviewed in comparison to other crops in the state, such as corn, grass hay, grass-legume hay, and alfalfa. The economic analysis includes an evaluation the costs of production for varying scales of operation, adjustment for seeding rates, land type (cropland or grassland), and annualized cost of establishment costs.

Given that there is no economic and production data in Switchgrass in Massachusetts, we develop a budget based on observations from other states in the United States that are closest to Massachusetts, two year data from a farm in New York, consultation with local farmers, state prices on certain inputs, and agronomic methods applicable to the region. We use several yield and seeding scenarios to depict potential scenarios of the production environment in Massachusetts. We use two scenarios (4t/ac and 6t/acre) that correspond to the yield range of 4.3 t/acre to 5.3 t/acre predicted by Graham et al (1995) for the period of 2005 and 2020 for the New England region.

## **3. GIS Analysis of Potential Acreage and Production.**

Land use coverage is analyzed using GIS for potential areas for Switchgrass production. This was done using a detailed and spatially explicit assessment of the landscape in Massachusetts. A major hurdle in feasibility studies, like Switchgrass production, is lack of historic data to assess potential acreage. One option is to develop potential scenarios that reflect various outcomes that can be expected in the future.

We use a scenario analysis that is based on land use type and allocation within a farm holding. We use three allocation scenarios and two yield scenarios in assign switchgrass potential in Massachusetts.

#### Scenarios:

1. Land allocation scenarios: 100% allocation; 50% allocation; and 25% allocation of the particular land use acreage to switchgrass production.
2. Yield scenarios: 4 ton per acre and 6 ton per acre (Based on projections by Graham et al., (1995)).

The results are evaluated for potential acreage and production potential by county through the state. The results are expressed as acreage and production, along with percentage contribution of each county.

The latest available land use layer for the state is obtained from MassGIS along with GIS data on administrative boundaries and road networks. These were combined into a GIS project for this analysis. Land use classes are then reclassified to isolate specific land classes in each scenario. The maps are presented both statewide and in three zones (Eastern, Central, and Western Massachusetts).

#### **Results:**

##### Agronomic Studies:

The field plantings in the project funded by Mass. Dept. of Agricultural Resources provided meaningful information for this economic analysis. Following the crop establishment in the summer of 2006 we were able to identify winter survival of the 12 varieties after two winters and the first year of growth after the first establishment year. Nine varieties showed potential with three either not surviving winter or a combination of winter kill and lack of seedling year establishment, with three of the nine having good stand densities, competitiveness with weeds, and higher yields. Following this past winter one of the three not growing in 2007 has shown signs of growth this spring. This indicates the seed was viable and lay dormant until this spring. Taking two seasons to germinate would be unacceptable to farmers and would have a major impact on economics for the crop. Variability in seedling vigor is a major problem in establishment resulting from poor seed quality (germination) and variation in seed dormancy. Resolving this problem is further confounded with seed company determinations of pure live seed that are provided as an indicator of seed vigor or germination.

Because growth is slow, switchgrass seedlings are not competitive with weeds in spring, especially with annual grassy weeds. Most broadleaf weeds can be controlled with triazine herbicides but few or no herbicides are labeled in Massachusetts for grass weeds. Methods to reduce the impact of early summer weeds such as delayed planting until after the spring weed flush may be helpful.

##### Production Budgets:

The cost of production for switchgrass for Massachusetts is presented in Table 1. The pre-harvest machinery for spreading fertilizer and chemical spraying is at \$20 per acre. This is based on average time for application in an acre. The estimated amounts of N, P, and K required are at 100, 10, and 90 lbs per acre of switchgrass. With 2007 prices of

0.55c, 0.35c, and 0.36c, the total cost of fertilizers is at \$90.90 per acre. The total chemical cost is at \$6.86 per acre.

The harvesting cost varied between the two scenarios - \$192 per acre for 4 ton per acre and \$252 ton per acre for the 6 ton per acre scenario. The difference is because of the higher yield in the second scenario of 6 ton per acre.

The total production cost in cropland for a yield of 4 ton per acre is at \$450.18 per acre, while it is \$398.27 per acre to cultivate in grassland. Under the scenario of 6t/acre, the cost per acre increase to \$510.18 per acre for cultivation in cropland and \$458.27 per acre in grassland.

The least cost per ton is cultivation of switchgrass in grassland with a 6 ton per acre yield potential (\$76/ton), followed by switchgrass production in cropland with 6 ton per acre (\$85/ton). The cost per ton is higher under 4 ton per acre scenario because of the economies of scale and difference in yield compared to \$6 ton per acre.

**Table 1. Switchgrass Cost and Production Budget in Massachusetts**

	4t/ac (25% reseeded)			6t/ac (25% reseeded)		
			\$/acre			\$/acre
<b>Preharvest Machinery</b>						
Spreading Fertilzer			10.00			10.00
Chemical spray			10.00			10.00
<b>Total Machinery cost</b>			<b>20.00</b>			<b>20.00</b>
<b>Operating expenses</b>	<b>price</b>	<b>amount</b>		<b>price</b>	<b>amount</b>	
N	0.55	100.00	55.00	0.55	100.00	55.00
P	0.35	10.00	3.50	0.35	10.00	3.50
K	0.36	90.00	32.40	0.36	90.00	32.40
herbicide						
atrazine	2.93	1.50	4.40	2.93	1.50	4.40
2,4D	1.63	1.50	2.45	1.63	1.50	2.45
<b>Total operating cost</b>			<b>97.74</b>			<b>97.74</b>
Interest of OC (9%)	9%		<b>8.80</b>	0.09		<b>8.80</b>
<b>Harvesting (Based \$65/hour)</b>						
mowing			48.00			48.00
raking			24.00			24.00
baling			60.00			90.00
staging/loading			60.00			90.00
<b>Total harvesting cost</b>			<b>192.00</b>			<b>252.00</b>
	<b>Cropland</b>		<b>Grassland</b>	<b>Cropland</b>		<b>Grassland</b>
Land charge	100.00		50.00	100.00		50.00
11 year establishment cost	26.71		25.73	26.71		25.73
reseeding cost	4.93		4.00	4.93		4.00
<b>production costs</b>	<b>450.18</b>		<b>398.27</b>	<b>510.18</b>		<b>458.27</b>
<b>costs per ton</b>	<b>112.54</b>		<b>99.57</b>	<b>85.03</b>		<b>76.38</b>

### **Potential acreage of Switchgrass in crop and pasture land in Massachusetts.**

Acreage potential under each allocation scenario is presented by county in Table 2. Out of total area of 5 million acres in the state, crop and pasture land accounts to 318,819 acres (6.16 %). With 100 % scenario, entire acreage can be allocated to switchgrass – an unlikely scenario but presents a maximum possible level. At 50% scenario, potential acreage is at 159,400 acres, and at 25 % scenario, 80,000 acres can be used in producing switchgrass. The highest potential is in Hampshire County with 12 percent, followed by Franklin (9%) and Berkshire (8%) counties. Bristol, Worcester, and Hampden counties also showed potential for switchgrass cultivation. The least potential is in the Suffolk County at less than 1% of the county acreage.

### **Potential production of Switchgrass in Massachusetts.**

Potential production of switchgrass under the two yield scenarios is presented for each county in Table 3. With a 4 ton per acre scenario and 100 % allocation potential, the maximum potential is at 1.3 million tons, while it is at a total of 1.9 million tons under 6 ton per acre scenario. Under a 4 ton per acre potential, the expected production is at 638,000 tons with 50% allocation and at 319,000 tons under 25% allocation scenario. Under a future potential of 6 ton per acre in yield, the expected production is at 956,000 tons with 50% allocation and at 478,000 tons under 25% allocation scenario. The highest production can be achieved from Worcester County (258,000 tons at 4 ton per acre and 387,000 tons at 6 ton per acre). This is followed by production from the Berkshire County (202,000 to 303,000 tons), Hampshire County (167,000 to 250,000 tons), Hampden County (90,500 to 136,000 tons) and Bristol County (102,000 to 153,000 tons).



**Table 1. Potential Acreage of Switchgrass in Cropland and Pasture in Massachusetts.**

<b>COUNTY</b>	<b>Area of Crop &amp; Pasture (Acres)</b>	<b>Area of County (Acres)</b>	<b>Potential Switchgrass Acreage (100%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (50%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (25%)</b>	<b>Percent of County Area</b>
BARNSTABLE	1,954.33	263,988.00	1,954.33	0.74	977.17	0.37	488.58	0.19
BERKSHIRE	50,478.14	605,697.00	50,478.14	8.33	25,239.07	4.17	12,619.53	2.08
BRISTOL	25,482.69	365,988.50	25,482.69	6.96	12,741.34	3.48	6,370.67	1.74
DUKES	2,994.37	70,335.60	2,994.37	4.26	1,497.18	2.13	748.59	1.06
ESSEX	19,489.80	329,540.10	19,489.80	5.91	9,744.90	2.96	4,872.45	1.48
FRANKLIN	41,119.89	463,739.80	41,119.89	8.87	20,559.95	4.43	10,279.97	2.22
HAMPDEN	22,607.48	405,796.90	22,607.48	5.57	11,303.74	2.79	5,651.87	1.39
HAMPSHIRE	41,728.32	348,972.60	41,728.32	11.96	20,864.16	5.98	10,432.08	2.99
MIDDLESEX	23,505.10	541,818.40	23,505.10	4.34	11,752.55	2.17	5,876.28	1.08
NANTUCKET	630.82	31,378.00	630.82	2.01	315.41	1.01	157.71	0.50
NORFOLK	8,253.58	261,462.20	8,253.58	3.16	4,126.79	1.58	2,063.40	0.79
PLYMOUTH	15,949.24	441,449.70	15,949.24	3.61	7,974.62	1.81	3,987.31	0.90
SUFFOLK	58.00	38,232.60	58.00	0.15	29.00	0.08	14.50	0.04
WORCESTER	64,566.99	1,010,699.00	64,566.99	6.39	32,283.49	3.19	16,141.75	1.60
<b>State Total</b>	<b>318,818.75</b>	<b>5,179,098.40</b>	<b>318,818.75</b>	<b>6.16</b>	<b>159,409.37</b>	<b>3.08</b>	<b>79,704.69</b>	<b>1.54</b>



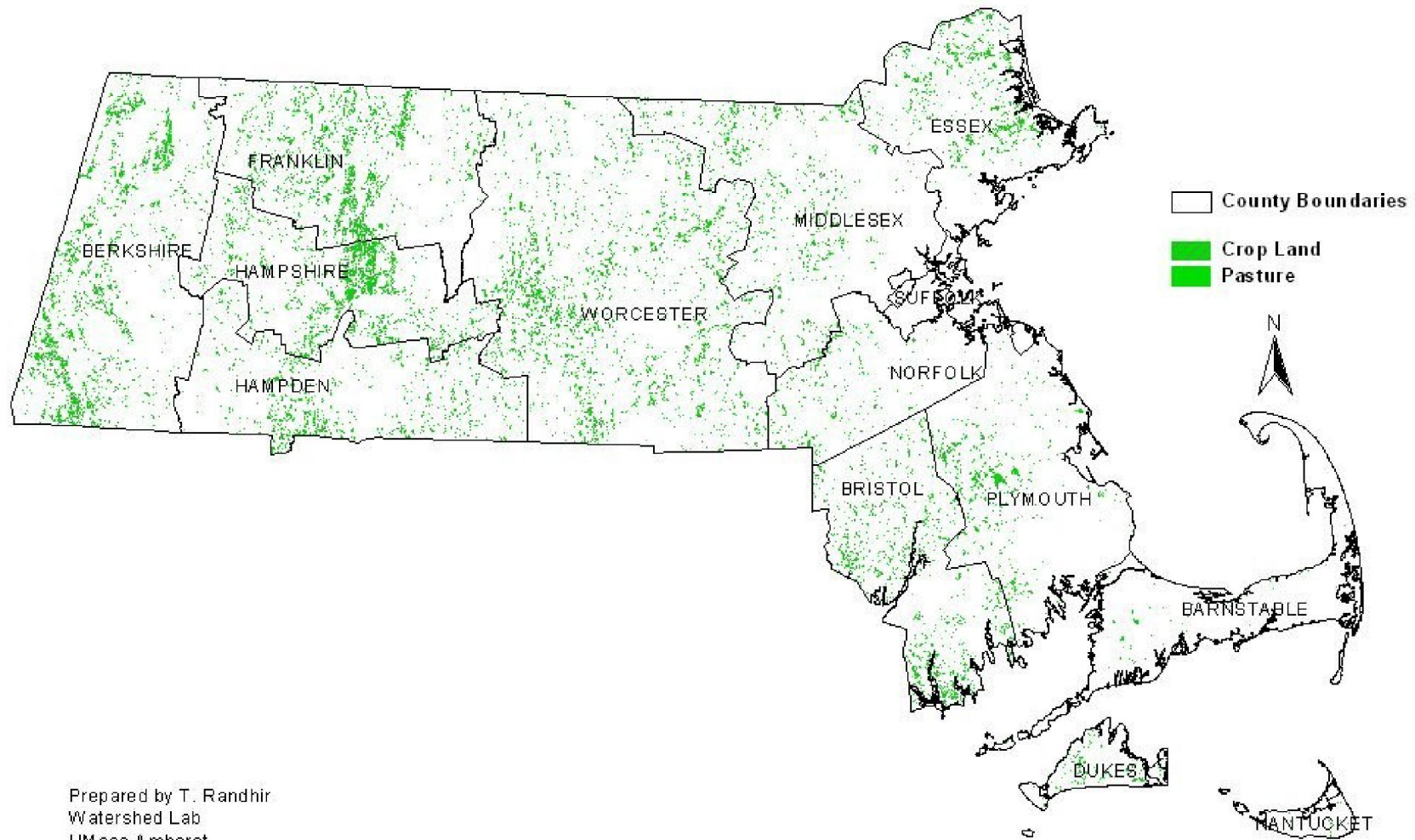
**Table 3. Potential Production of Switchgrass in Cropland and Pasture in Massachusetts.**

COUNTY	4 tons/acre			6 tons/acre		
	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)
BARNSTABLE	7,817.32	3,908.66	1,954.33	11,725.99	5,862.99	2,931.50
BERKSHIRE	201,912.56	100,956.28	50,478.14	302,868.83	151,434.42	75,717.21
BRISTOL	101,930.74	50,965.37	25,482.69	152,896.11	76,448.06	38,224.03
DUKES	11,977.47	5,988.74	2,994.37	17,966.21	8,983.11	4,491.55
ESSEX	77,959.19	38,979.60	19,489.80	116,938.79	58,469.39	29,234.70
FRANKLIN	164,479.57	82,239.79	41,119.89	246,719.36	123,359.68	61,679.84
HAMPDEN	90,429.94	45,214.97	22,607.48	135,644.91	67,822.45	33,911.23
HAMPSHIRE	166,913.26	83,456.63	41,728.32	250,369.89	125,184.95	62,592.47
MIDDLESEX	94,020.41	47,010.20	23,505.10	141,030.61	70,515.31	35,257.65
NANTUCKET	2,523.29	1,261.64	630.82	3,784.93	1,892.46	946.23
NORFOLK	33,014.33	16,507.16	8,253.58	49,521.49	24,760.75	12,380.37
PLYMOUTH	63,796.98	31,898.49	15,949.24	95,695.47	47,847.73	23,923.87
SUFFOLK	231.99	116.00	58.00	347.99	173.99	87.00
WORCESTER	258,267.94	129,133.97	64,566.99	387,401.91	193,700.96	96,850.48
<b>State Total</b>	<b>1,275,274.99</b>	<b>637,637.50</b>	<b>318,818.75</b>	<b>1,912,912.49</b>	<b>956,456.25</b>	<b>478,228.12</b>

## **Spatial distribution of Switchgrass production potential in crop and pasture land**

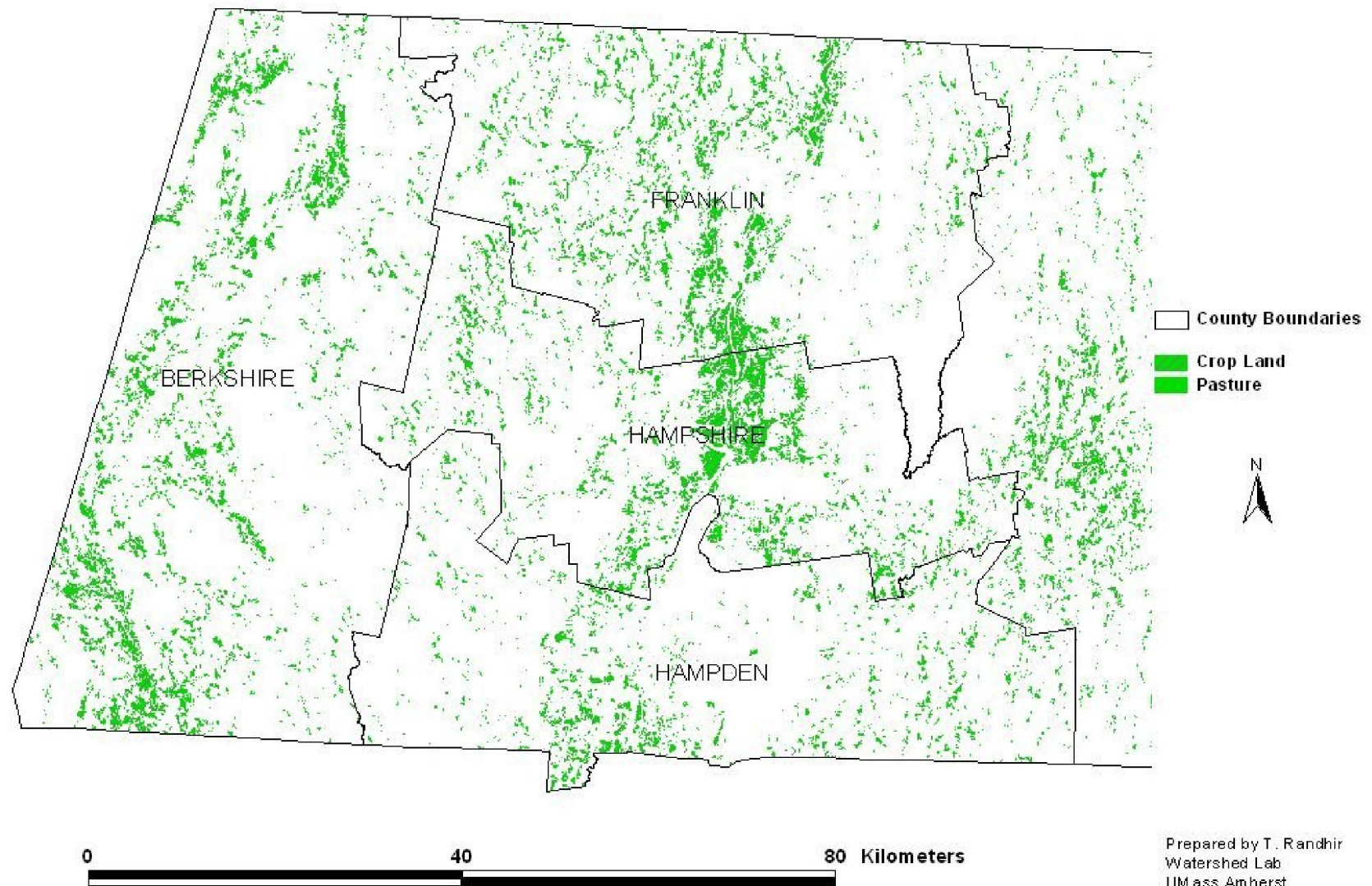
The spatial distribution of switchgrass potential in crop and pasture land is presented in Figures 1 to 4. While the spread is even throughout the state, highest concentration of acreage is in the western Massachusetts along the Connecticut River valley in Hampshire and Franklin counties. Other concentration is in the Housatonic valley in the Berkshire County. In Western Massachusetts, larger potential parcels are located around the Connecticut River in Hampshire, Franklin, and Hampden counties. In central Massachusetts, larger clustering of potential acres is observed in southwest portion of the Worcester County.

## Massachusetts - Potential Switchgrass in Crop & Pasture Land



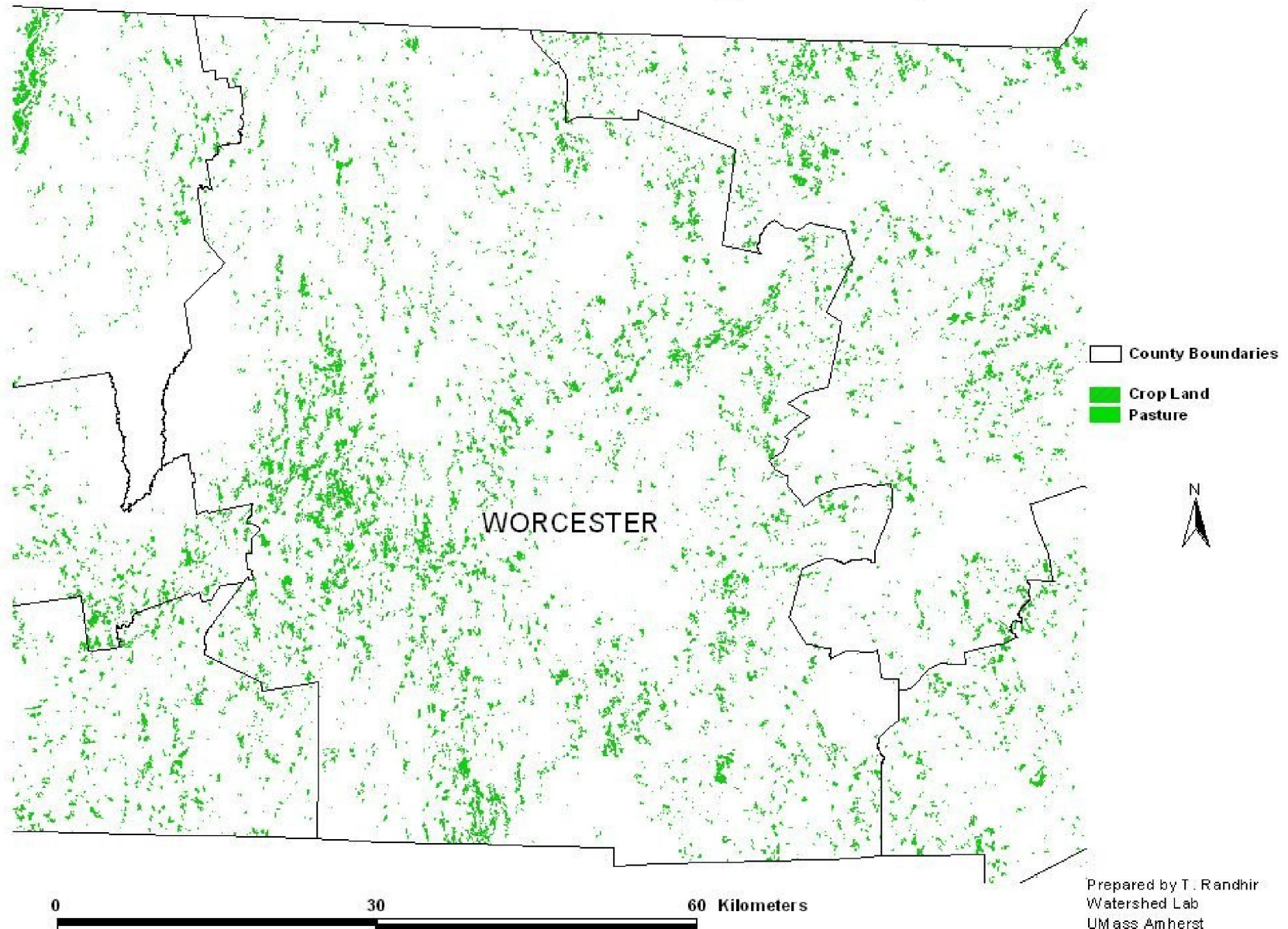
Prepared by T. Randhir  
Watershed Lab  
UMass Amherst

## Western Massachusetts - Potential Switchgrass in Crop & Pasture Land

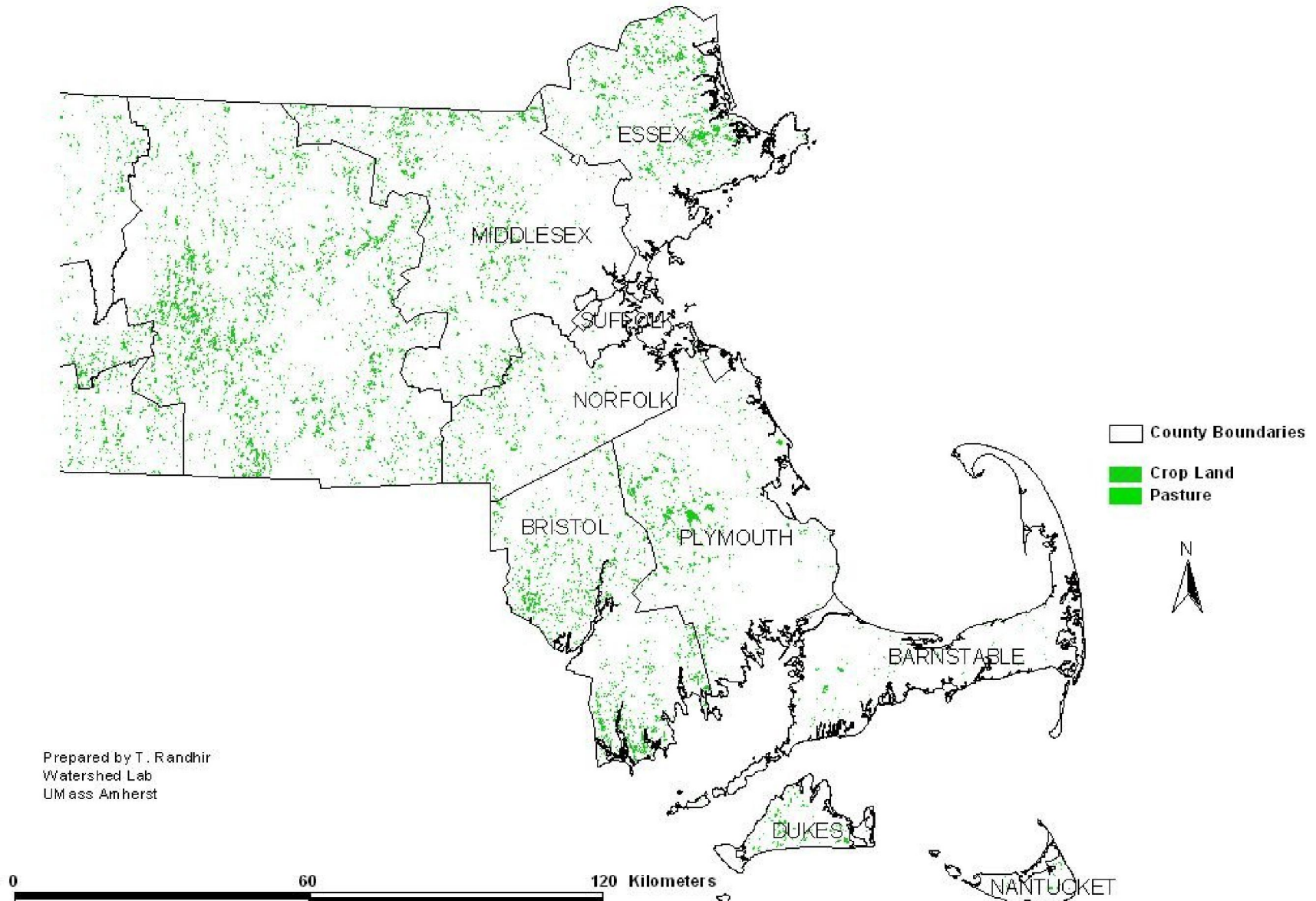




## Central Massachusetts - Potential Switchgrass in Crop & Pasture Land



## Eastern Massachusetts - Potential Switchgrass in Crop & Pasture Land



### **Potential acreage of Switchgrass in urban and nonurban open land in Massachusetts**

Acreage potential under each allocation scenario is presented by county in Table 4. Out of total area of 5 million acres in the state, urban and nonurban open land accounts to 148,000 acres (2.86 %). With 100 % scenario, entire acreage can be allocated to switchgrass – an unlikely scenario but presents a maximum possible level. At 50% scenario, potential acreage is at 74,000 acres, and at 25 % scenario, 37,000 acres can be used in producing switchgrass. The highest potential is in Nantucket County with 48 percent, followed by Dukes (11%) and Barnstable (7%) counties. Other counties showed less potential (2% to 3 %) for switchgrass cultivation. The least potential is in Franklin County at 1.6 % of the county acreage.

### **Potential production of Switchgrass in urban and nonurban open land in Massachusetts**

Potential production of switchgrass under the two yield scenarios is presented for each county in Table 5. With a 4 ton per acre scenario and 100 % allocation potential, the maximum potential is at 592,000 tons, while it is at a total of 888,000 tons under 6 ton per acre scenario. Under a 4 ton per acre potential, the expected production is at 296,000 tons with 50% allocation and at 148,000 tons under 25% allocation scenario. Under a potential of 6 ton per acre, the expected production is at 444,000 tons with 50% allocation and at 222,000 tons under 25% allocation scenario. The highest production can be achieved from Worcester County (89,000 tons at 4 ton per acre and 133,000 tons at 6 ton per acre). This is followed by production from the Barnstable County (71,000 to 107,000 tons), Nantucket County (61,000 to 91,000 tons), Middlesex County (47,000 to 71,000 tons) and Berkshire County (43,000 to 65,000 tons).



**Table 4. Potential Acreage of Switchgrass in Urban and Nonurban Open Land in Massachusetts.**

<b>COUNTY</b>	<b>Area in Urban &amp; Non-Urban Open Land</b>	<b>Area of County (Acres)</b>	<b>Potential Switchgrass Acreage (100%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (50%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (25%)</b>	<b>Percent of County Area</b>
BARNSTABLE	17,839.55	263,988.00	17,839.55	6.76	8,919.78	3.38	4,459.89	1.69
BERKSHIRE	10,827.53	605,697.00	10,827.53	1.79	5,413.77	0.89	2,706.88	0.45
BRISTOL	12,613.48	365,988.50	12,613.48	3.45	6,306.74	1.72	3,153.37	0.86
DUKES	7,559.94	70,335.60	7,559.94	10.75	3,779.97	5.37	1,889.98	2.69
ESSEX	10,352.76	329,540.10	10,352.76	3.14	5,176.38	1.57	2,588.19	0.79
FRANKLIN	7,296.49	463,739.80	7,296.49	1.57	3,648.25	0.79	1,824.12	0.39
HAMPDEN	8,794.58	405,796.90	8,794.58	2.17	4,397.29	1.08	2,198.64	0.54
HAMPSHIRE	5,812.68	348,972.60	5,812.68	1.67	2,906.34	0.83	1,453.17	0.42
MIDDLESEX	11,810.66	541,818.40	11,810.66	2.18	5,905.33	1.09	2,952.66	0.54
NANTUCKET	15,150.10	31,378.00	15,150.10	48.28	7,575.05	24.14	3,787.53	12.07
NORFOLK	6,641.44	261,462.20	6,641.44	2.54	3,320.72	1.27	1,660.36	0.64
PLYMOUTH	10,016.99	441,449.70	10,016.99	2.27	5,008.49	1.13	2,504.25	0.57
SUFFOLK	1,120.09	38,232.60	1,120.09	2.93	560.05	1.46	280.02	0.73
WORCESTER	22,179.22	1,010,699.00	22,179.22	2.19	11,089.61	1.10	5,544.81	0.55
<b>Grand Total</b>	<b>148,015.51</b>	<b>5,179,098.40</b>	<b>148,015.51</b>	<b>2.86</b>	<b>74,007.76</b>	<b>1.43</b>	<b>37,003.88</b>	<b>0.71</b>

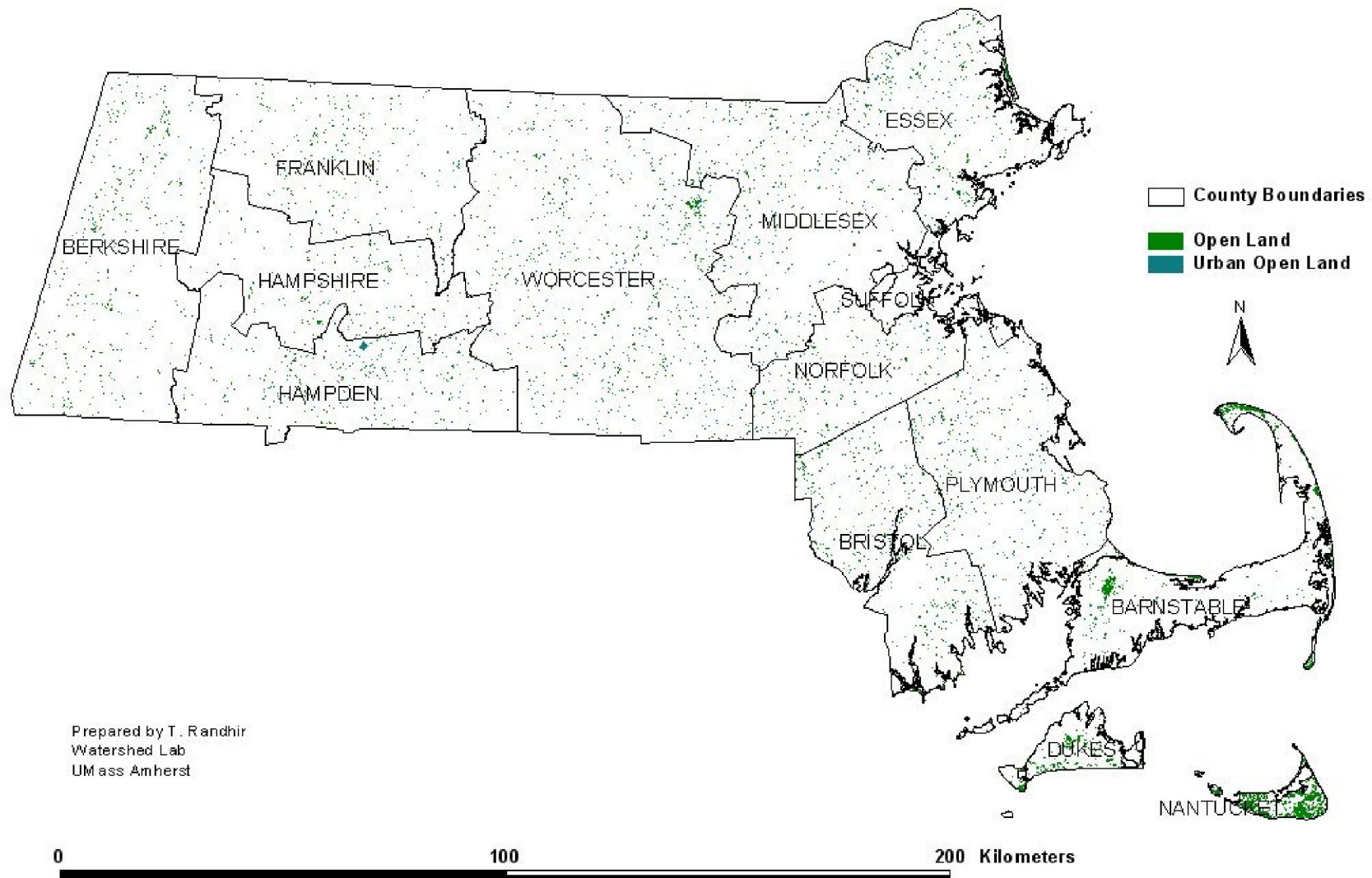
**Table 5. Potential Production of Switchgrass in Urban and Nonurban Open Land in Massachusetts.**

COUNTY	4 tons/acre			6 tons/acre		
	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)
BARNSTABLE	71,358.20	35,679.10	17,839.55	107,037.31	53,518.65	26,759.33
BERKSHIRE	43,310.13	21,655.07	10,827.53	64,965.20	32,482.60	16,241.30
BRISTOL	25,226.95	12,613.48	75,680.85	37,840.43	18,920.21	38,224.03
DUKES	15,119.88	7,559.94	45,359.63	22,679.82	11,339.91	4,491.55
ESSEX	20,705.53	10,352.76	62,116.58	31,058.29	15,529.15	29,234.70
FRANKLIN	29,185.97	14,592.99	7,296.49	43,778.96	21,889.48	10,944.74
HAMPDEN	35,178.31	17,589.16	8,794.58	52,767.47	26,383.73	13,191.87
HAMPSHIRE	23,250.71	11,625.36	5,812.68	34,876.07	17,438.03	8,719.02
MIDDLESEX	47,242.63	23,621.32	11,810.66	70,863.95	35,431.98	17,715.99
NANTUCKET	60,600.42	30,300.21	15,150.10	90,900.63	45,450.31	22,725.16
NORFOLK	26,565.76	13,282.88	6,641.44	39,848.64	19,924.32	9,962.16
PLYMOUTH	40,067.95	20,033.98	10,016.99	60,101.93	30,050.96	15,025.48
SUFFOLK	4,480.37	2,240.18	1,120.09	6,720.55	3,360.28	1,680.14
WORCESTER	88,716.88	44,358.44	22,179.22	133,075.32	66,537.66	33,268.83
<b>State Total</b>	<b>592,062.06</b>	<b>296,031.03</b>	<b>148,015.51</b>	<b>888,093.09</b>	<b>444,046.54</b>	<b>222,023.27</b>

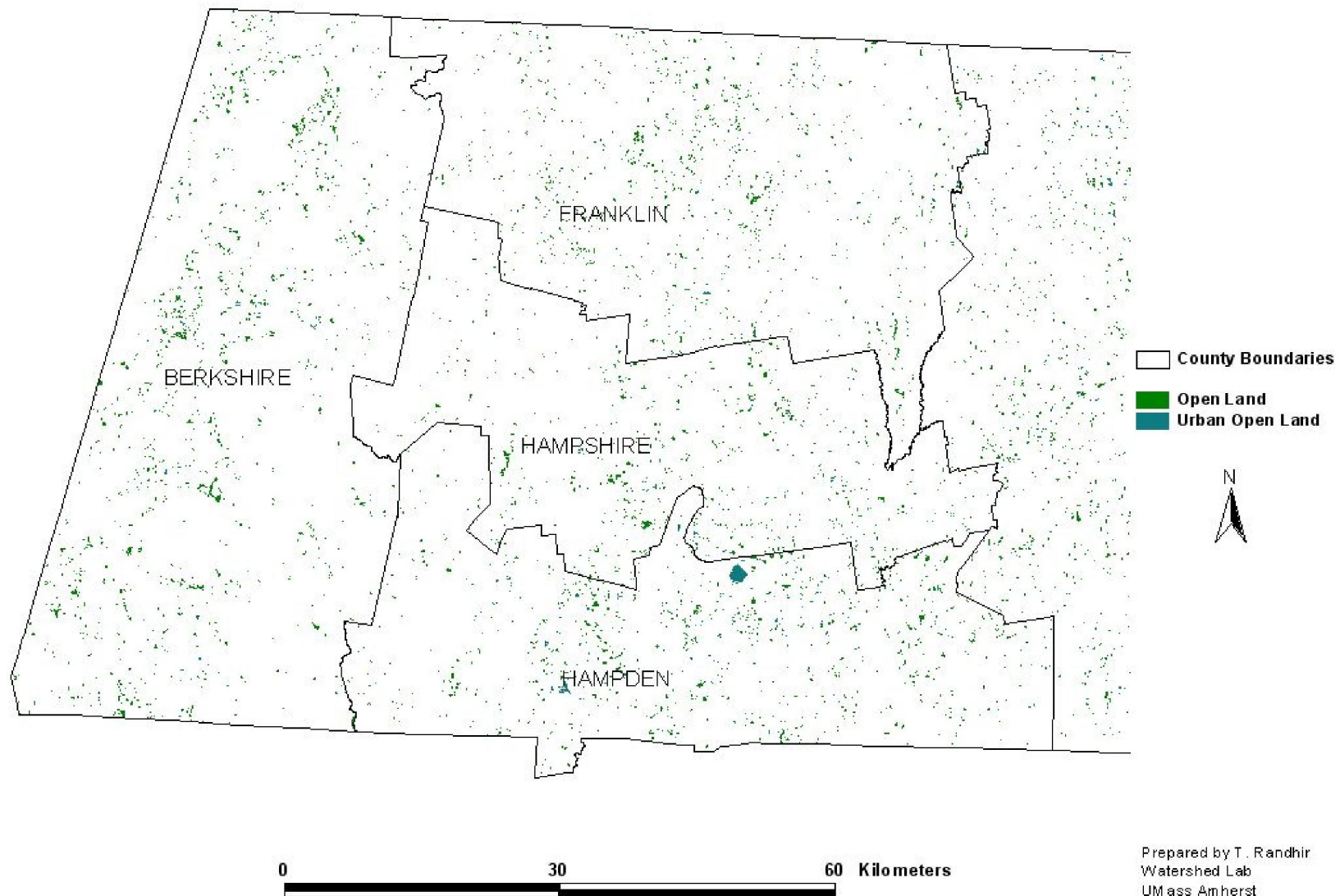
### **Spatial distribution of Switchgrass production potential in crop and pasture land**

The spatial distribution of switchgrass potential in urban and nonurban open land is presented in Figures 5 to 8. While the spread is even throughout the state, there is no observable concentration of acreage in the state.

## Massachusetts - Potential Switchgrass in Urban & Non-Urban Open Lands

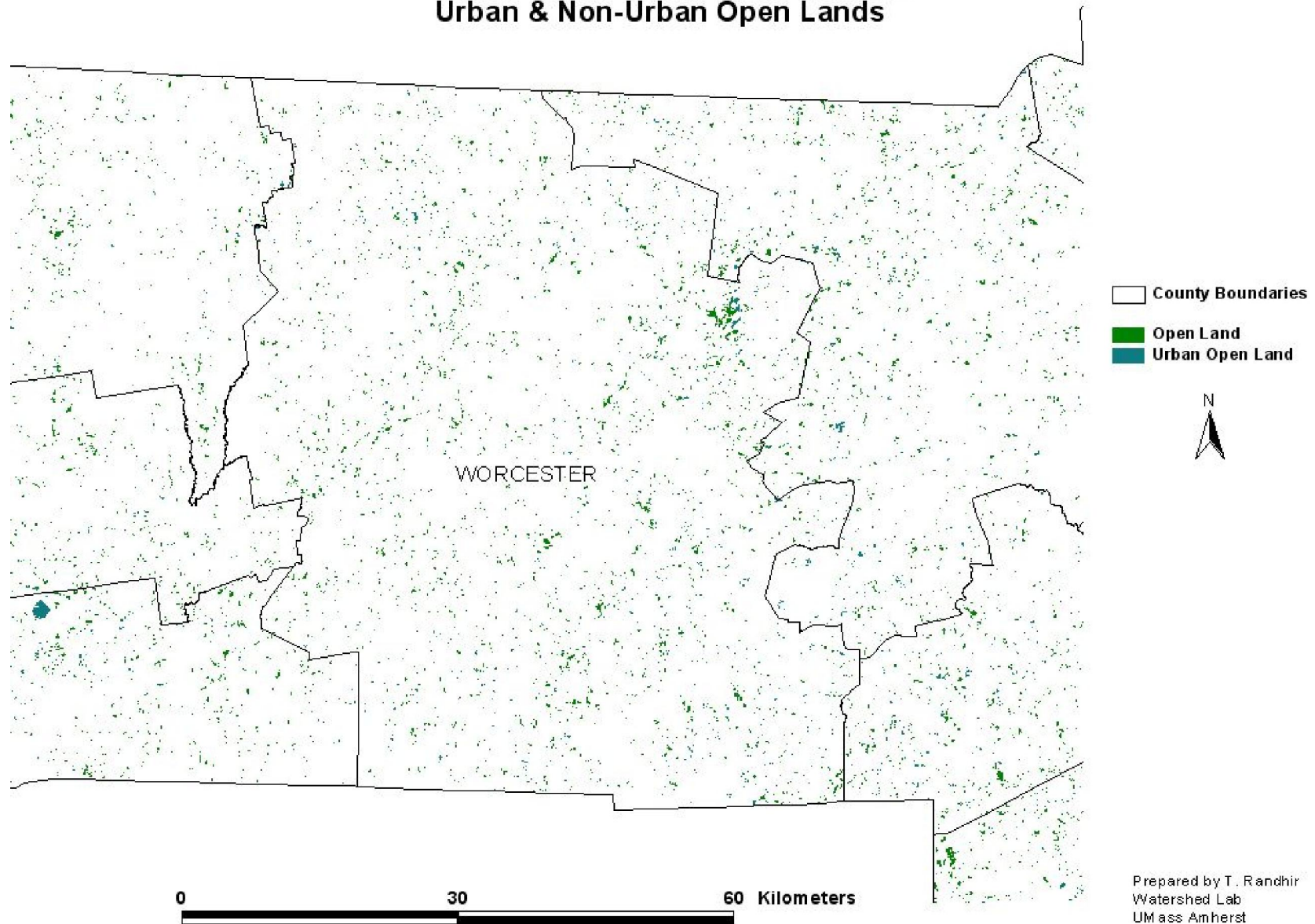


## Western Massachusetts - Potential Switchgrass in Urban & Non-Urban Open Lands

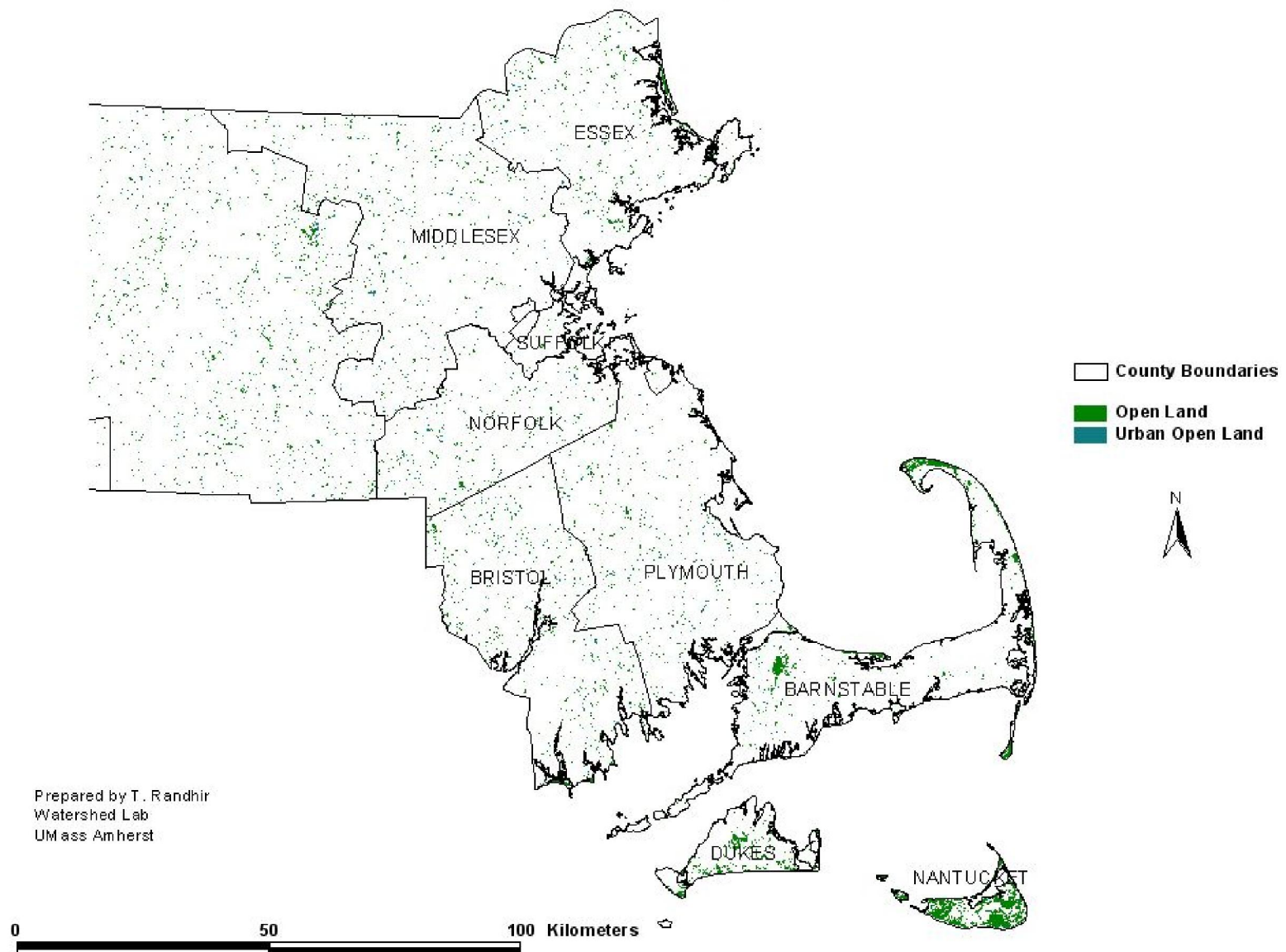




## Central Massachusetts - Potential Switchgrass in Urban & Non-Urban Open Lands



## Eastern Massachusetts - Potential Switchgrass in Urban & Non-Urban Open Lands





### **Potential acreage of Switchgrass in cropland, pasture, and urban and nonurban open land in Massachusetts**

Acreage potential under each allocation scenario is presented by county in Table 6. Out of total area of 5 million acres in the state, crop, pasture, and open land accounts to 467,000 acres (9 %). With 100 % scenario, entire acreage can be allocated to switchgrass – an unlikely scenario but presents a maximum possible level. At 50% scenario, potential acreage is at 233,000 acres, and at 25 % scenario, 117,000 acres can be used in producing switchgrass. The highest potential is in Nantucket County with 50 percent, followed by Dukes (15%) and Hampshire (14%) counties. Other counties showed potential ranging from 3 to 10 percentages for switchgrass cultivation. The least potential is in Suffolk County at 1.6 % of the county acreage.

### **Potential production of Switchgrass in cropland, pasture, and urban and nonurban open land in Massachusetts**

Potential production of switchgrass under the two yield scenarios is presented for each county in Table 7. With a 4 ton per acre scenario and 100 % allocation potential, the maximum potential is at 1.9 million tons, while it is at a total of 2.8 million tons under 6 ton per acre scenario. Under a 4 ton per acre potential, the expected production is at 934,000 tons with 50% allocation and at 467,000 tons under 25% allocation scenario. Under a potential of 6 ton per acre, the expected production is at 1.4 million tons with 50% allocation and at 700,000 tons under 25% allocation scenario. The highest production can be achieved from Worcester County (347,000 tons at 4 ton per acre and 520,000 tons at 6 ton per acre). This is followed by production from the Berkshire County (245,000 tons at 4 ton per acre and 368,000 tons at 6 ton per acre), Franklin county (194,000 to 290,000 tons), Hampshire county (190,000 to 285,000 tons), and Middlesex county (141,000 to 212,000 tons).

**Table 6. Potential Acreage of Switchgrass in Crop, Pasture, and Urban and Nonurban Open Land in Massachusetts.**

<b>COUNTY</b>	<b>Area in Crop &amp; Pasture &amp; Open land</b>	<b>Area of County (Acres)</b>	<b>Potential Switchgrass Acreage (100%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (50%)</b>	<b>Percent of County Area</b>	<b>Potential Switchgrass Acreage (25%)</b>	<b>Percent of County Area</b>
BARNSTABLE	19,793.88	263,988.00	19,793.88	7.50	9,896.94	3.75	4,948.47	1.87
BERKSHIRE	61,305.67	605,697.00	61,305.67	10.12	30,652.84	5.06	15,326.42	2.53
BRISTOL	38,096.16	365,988.50	38,096.16	10.41	19,048.08	5.20	9,524.04	2.60
DUKES	10,554.31	70,335.60	10,554.31	15.01	5,277.15	7.50	2,638.58	3.75
ESSEX	29,842.56	329,540.10	29,842.56	9.06	14,921.28	4.53	7,460.64	2.26
FRANKLIN	48,416.39	463,739.80	48,416.39	10.44	24,208.19	5.22	12,104.10	2.61
HAMPDEN	31,402.06	405,796.90	31,402.06	7.74	15,701.03	3.87	7,850.52	1.93
HAMPSHIRE	47,540.99	348,972.60	47,540.99	13.62	23,770.50	6.81	11,885.25	3.41
MIDDLESEX	35,315.76	541,818.40	35,315.76	6.52	17,657.88	3.26	8,828.94	1.63
NANTUCKET	15,780.93	31,378.00	15,780.93	50.29	7,890.46	25.15	3,945.23	12.57
NORFOLK	14,895.02	261,462.20	14,895.02	5.70	7,447.51	2.85	3,723.76	1.42
PLYMOUTH	25,966.23	441,449.70	25,966.23	5.88	12,983.12	2.94	6,491.56	1.47
SUFFOLK	1,178.09	38,232.60	1,178.09	3.08	589.04	1.54	294.52	0.77
WORCESTER	86,746.21	1,010,699.00	86,746.21	8.58	43,373.10	4.29	21,686.55	2.15
<b>Grand Total</b>	<b>466,834.26</b>	<b>5,179,098.40</b>	<b>466,834.26</b>	<b>9.01</b>	<b>233,417.13</b>	<b>4.51</b>	<b>116,708.57</b>	<b>2.25</b>

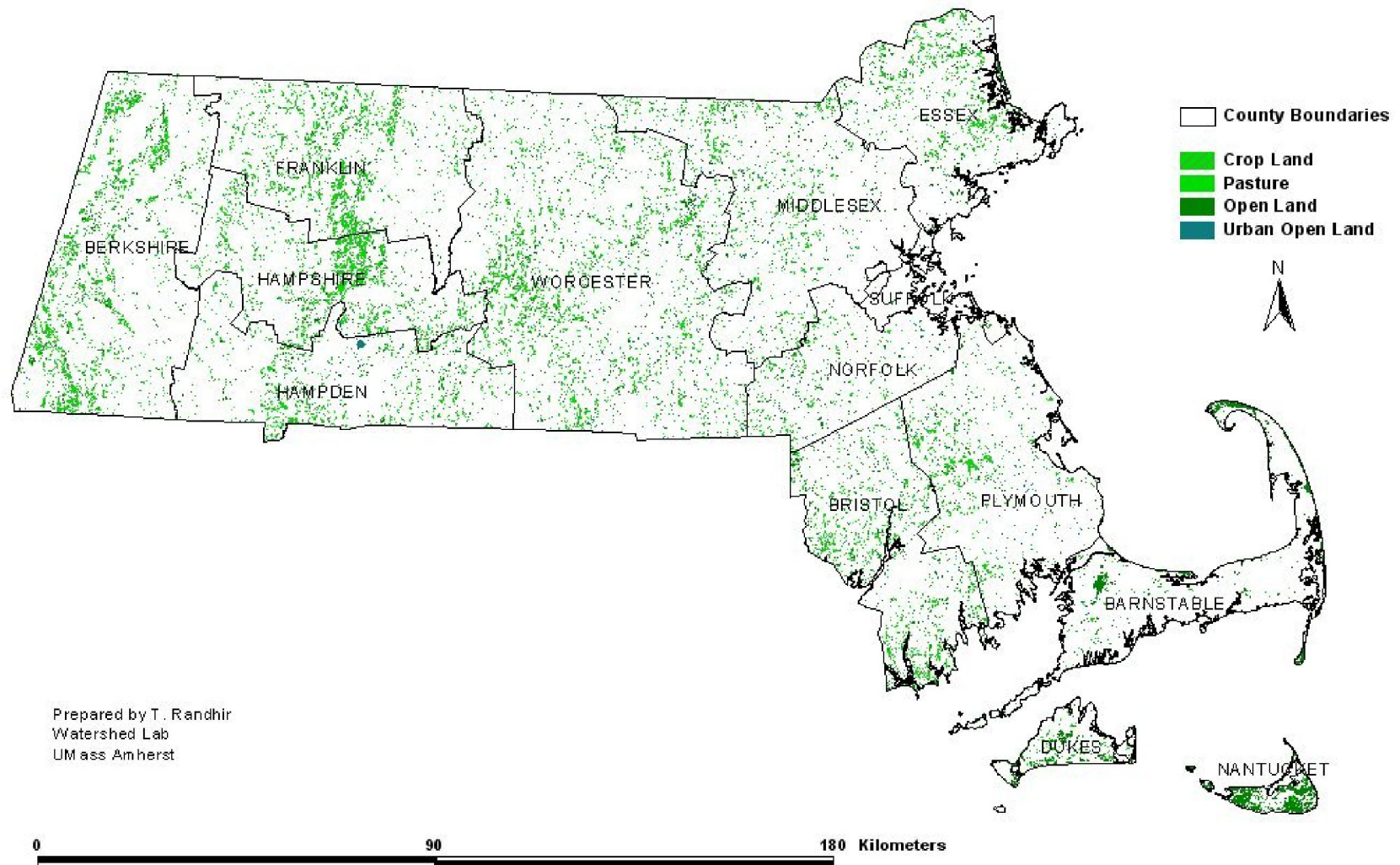
**Table 7. Potential Production of Switchgrass in Crop, Pasture, and Urban and Nonurban Open Land in Massachusetts.**

COUNTY	4 tons/acre			6 tons/acre		
	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)	100% Scenario Potential Production (tons)	50% Scenario Potential Production (tons)	25% Scenario Potential Production (tons)
BARNSTABLE	79,175.53	39,587.76	19,793.88	118,763.29	59,381.65	29,690.82
BERKSHIRE	245,222.69	122,611.34	61,305.67	367,834.03	183,917.01	91,958.51
BRISTOL	76,192.32	38,096.16	228,576.96	114,288.48	57,144.24	38,224.03
DUKES	21,108.61	10,554.31	63,325.84	31,662.92	15,831.46	4,491.55
ESSEX	59,685.12	29,842.56	179,055.37	89,527.69	44,763.84	29,234.70
FRANKLIN	193,665.55	96,832.77	48,416.39	290,498.32	145,249.16	72,624.58
HAMPDEN	125,608.25	62,804.13	31,402.06	188,412.38	94,206.19	47,103.09
HAMPSHIRE	190,163.98	95,081.99	47,540.99	285,245.96	142,622.98	71,311.49
MIDDLESEX	141,263.04	70,631.52	35,315.76	211,894.56	105,947.28	52,973.64
NANTUCKET	63,123.70	31,561.85	15,780.93	94,685.55	47,342.78	23,671.39
NORFOLK	59,580.09	29,790.04	14,895.02	89,370.13	44,685.07	22,342.53
PLYMOUTH	103,864.93	51,932.47	25,966.23	155,797.40	77,898.70	38,949.35
SUFFOLK	4,712.36	2,356.18	1,178.09	7,068.54	3,534.27	1,767.13
WORCESTER	346,984.82	173,492.41	86,746.21	520,477.23	260,238.62	130,119.31
<b>State Total</b>	<b>1,867,337.05</b>	<b>933,668.53</b>	<b>466,834.26</b>	<b>2,801,005.58</b>	<b>1,400,502.79</b>	<b>700,251.39</b>

### **Spatial distribution of Switchgrass production potential in crop, pasture, and urban and nonurban open land in Massachusetts**

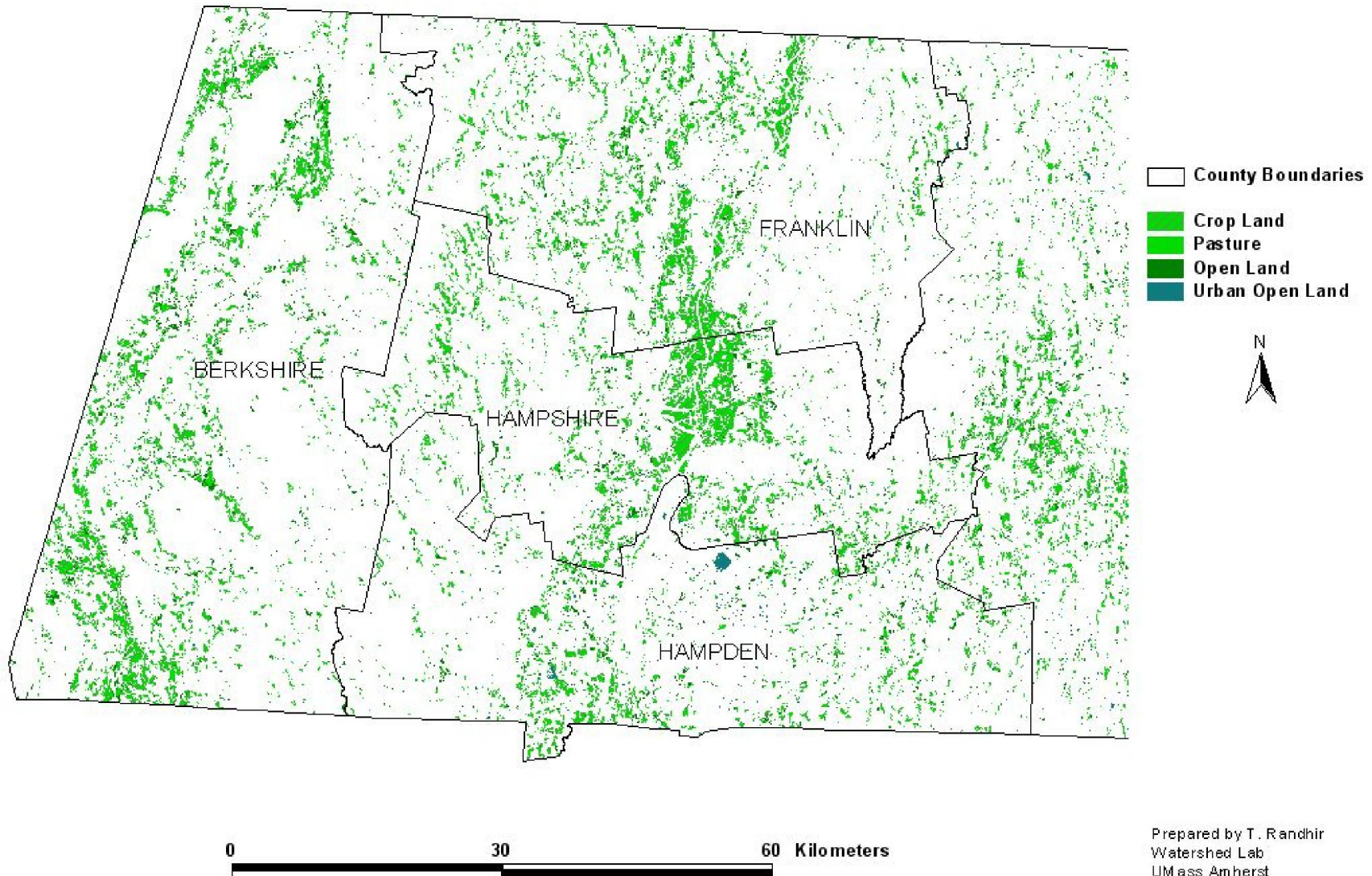
The spatial distribution of switchgrass potential in crop and pasture land is presented in Figures 9 to 12. While the spread is even throughout the state, highest concentration of acreage is in the western Massachusetts along the Connecticut River valley in Hampshire and Franklin counties. Other concentration is in the Housatonic valley in the Berkshire County. In Western Massachusetts, larger potential parcels are located around the Connecticut River in Hampshire, Franklin, and Hampden counties. In central Massachusetts, larger clustering of potential acres is observed in southwest portion of the Worcester County.

## Massachusetts - Potential Switchgrass in Agricultural Lands & Urban & Non-Urban Open Lands



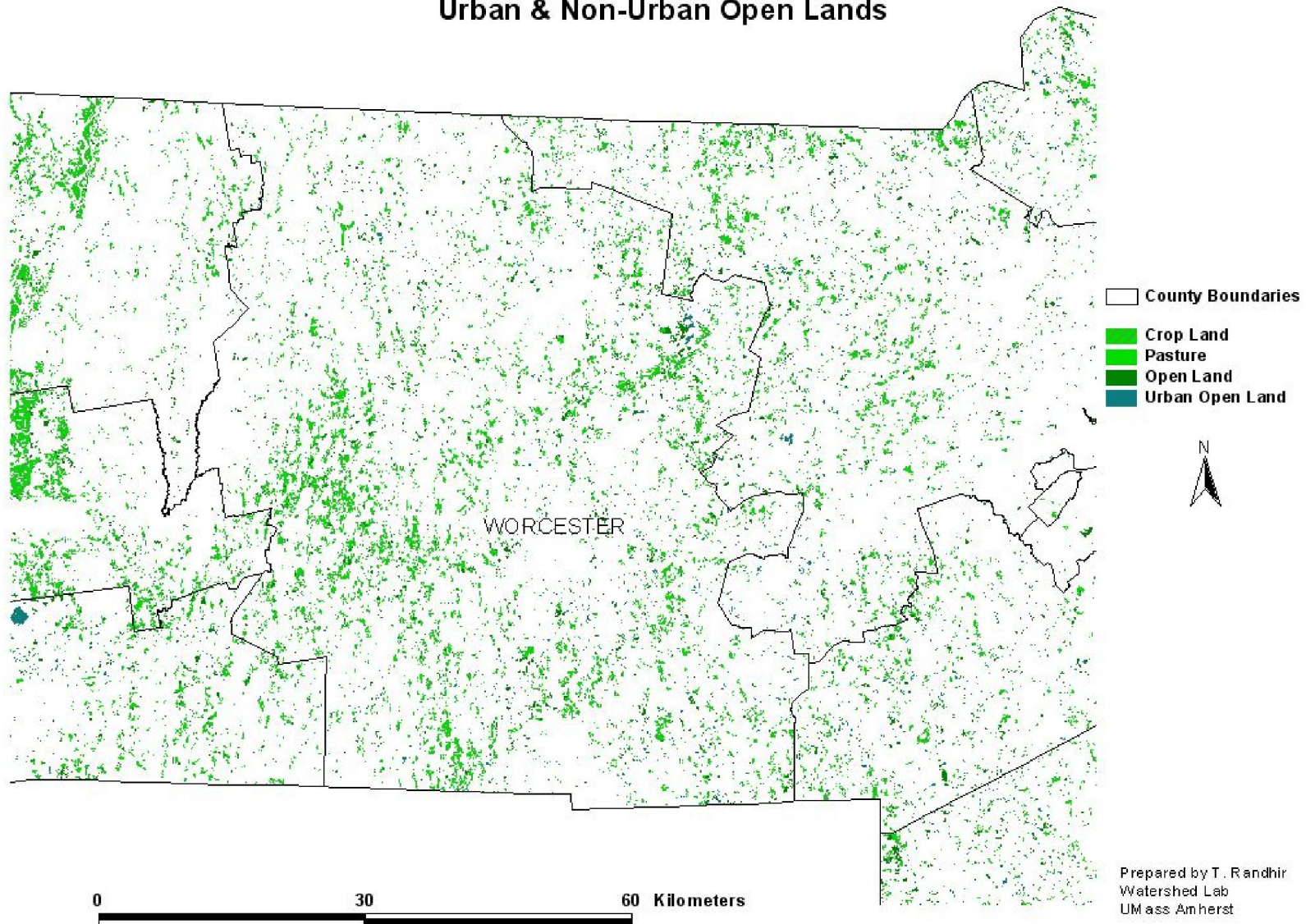


## Western Massachusetts - Potential Switchgrass in Agricultural Lands & Urban and Non-Urban Open Lands



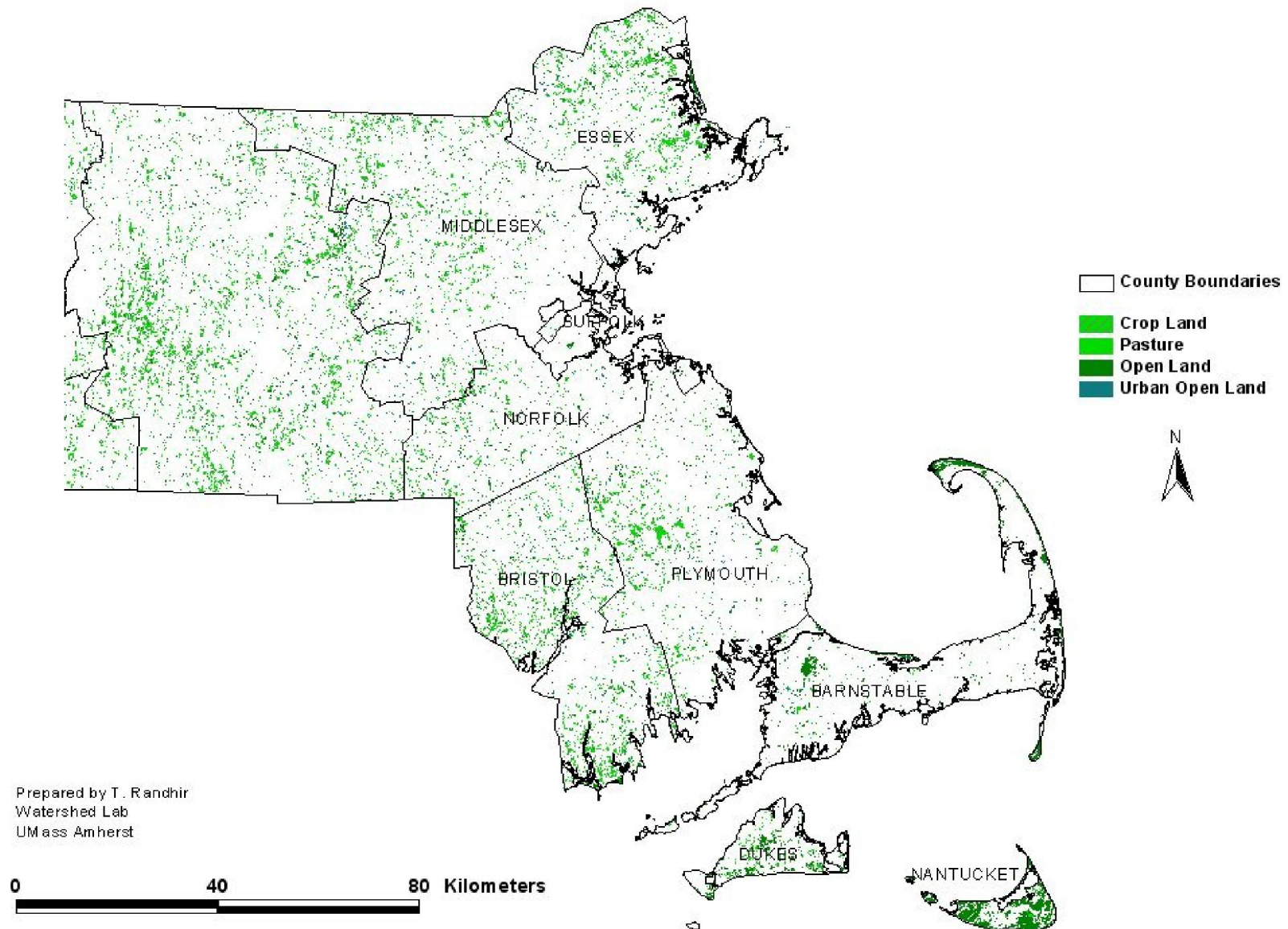


## Central Massachusetts - Potential Switchgrass in Agricultural Lands & Urban & Non-Urban Open Lands





## Eastern Massachusetts - Potential Switchgrass in Agricultural Lands & Urban & Non-Urban Open Lands



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